Study on specifications of farmland shelterbelt net in Northeastern Plain of China

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Abstracts: The farmland shelterbelts in Northeastern Plain of China have formed relatively complete net system. The functions of shelterbelt net in omnibearing wind check and prevention of frostbite as well as the field of integrated climate effect within shelterbelt net were analyzed, through located observation of meteorological factors. Within the shelterbelt net, the area with more than 10% efficiency of omnibearing wind check was determined as benefited area. The analysis of yield and quality of crops indicated that the sheltering range of shelterbelt net was 25 times tree height. The mature heights of the various varieties of poplar composed the shelterbelts were determined according to their height growth. Based on the comprehensive analysis above, the suitable size of farmland shelterbelt net in Northeastern Plain of China was decided to be 400 m×400 m.

Keywords: Farmland shelterbelt; Protective benefit; Shelterbelt net; Specifications, Wind-checking efficiency

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Introduction

Studies on windbreak benefit were conducted as early as the 1950s (George *et al.* 1963; Hu *et al.* 1990, Li *et al.* 2002). The early studies, however, mainly focused on the determination of distribution condition of wind speed, temperature, humidity, as well as crop yield and quality in two sides of windbreak belts in single-strip windbreak and in single direction, which have been not practicable to a perfect farmland shelterbelt net of today (Sun *et al.* 1999; Wu *et al.* 2001).

Constructing farmland shelterbelts in Northeastern plain of China began as early as in the 1950s and some shelterbelts have had a history of half century (Cao 1983; Xiang 1989). In particular, its construction speed was greatly accelerated during the first-stage and second-stage constructions of the Project of Sanbei (Three North regions) Protective Plantations (Zhu 1985). Integrated system of farmland shelterbelt nets in Northeastern plain had been formed since then. Most of the shelterbelt nets were set in size of 500 m×500 m. However whether this standard size is suitable remain a question and lacks theoretical and practical evidence.

Zhu Jiao-jun *et al.* (2002) studied the spacing interval between principal tree windbreaks and provided a determining method of interval distance of main belts. Our study made comprehensive analysis for various meteorological factors within the shelterbelt nets and in all directions during whole growth season of crop and evaluated the benefit distribution field within shelterbelt nets by comprehensive benefit parameter equation with omnibearing temperature, humidity, and wind. Meanwhile, crop yield and quality was determined and analyzed. Mature height of farmland shelterbelt for several main varieties of poplars was decided on the analysis of tree height growth (Zhou, *et al.* 2001). Finally, the suitable defense range of shelterbelt nets was appraised.

Study areas

The study area is located at the eastern part of Sanbei (Three North) region, including 53 counties distributed in middle and western part of Liaoning, Jilin, and Heilongjiang provinces, covering a total area of 200 050 km^2, with an elevation of 50-200 m above sea level. The typical soils are back soil, meadow soil, chernozem and swamp soil with thicker soil layer and higher fertility. This region is a main production base of commercial grain (wheat, maize, soybean, broomcorn, and millet) in our country.

The study area at middle temperature zone has continent monsoon climate, characterized by longer and colder winter, shorter, warmer and humid summer, and strong wind in spring and autumn. The weather here is very unstable. Quantity of heat in whole area increases by degree from the north to the south. Average air temperature is -24~-10°C in the coldest month and 21~25°C in the warmest month, with an annual average air temperature of 0-8°C and an annual range of temperature of 34~44°C. The accumulated temperature of ≥10°C is 2 383~3 382°C. Frostless period is 120-170 days. The climatic condition can basically meet the needs of reaping on crop a year and the growth of trees and grass. The precipitation deceases by degree from the eastern-south to western-north. The study area is divided into sub-wetness area and sub-aridity area. Annual precipitation is 350~650mm, and 80% of it occurs between May and September, which can basically satisfy the needs of grazing, trees, shrubs and dry crops. In

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spring, rainfall is less but likely occurrence of wind and drought, due to the unequal space-time distribution of water and heat, greatly impacting spring sowing, high yield, and stable production of agriculture and herd.

Study method

Observation of meteorological factors

The located observation was carried out in Zhaodong city. The shelterbelt was composed of 8-yr-old *Populus xiaohe* T.S.H. wangexc wang et Tung (5 lines and 7 meter breadth) and its average tree height was 14 m at the time. The net size was 500 m×500 m, with a ventilation coefficient of 0.59-0.77. Observation plots were set up in all directions within shelterbelt net (Fig. 1) and full automatic meteorology stations were adopted to measure the wind speed, temperature, humidity, dew temperature, and vapor pressure at the height of 1.5 m within the shelterbelt net. Precipitation, evaporation, radiation, snowfall distribution, ground surface temperature and underground temperature were measured by routine instrument.

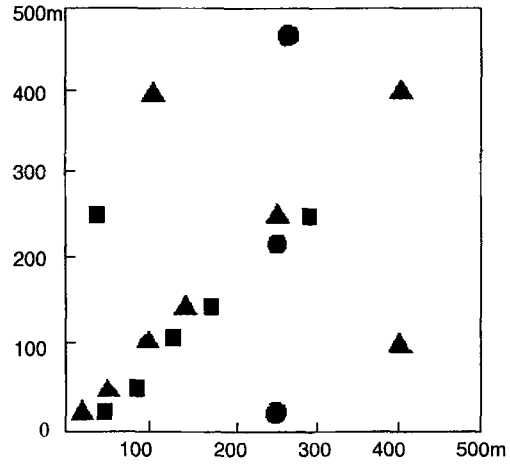


Fig.1 Distribution of observation point in a 500 m ×500 m shelterbelt net

▲-Integrated automatic instrument (including common thermometers)
■-Observation points and evaporation precipitation
●-Observation points of solar radiation

Measurement of crop yield and quality

Within the same shelterbelt net, for main shelterbelt net, observation points distributed were perpendicular to the main belt. Root, stem, leaf, spike, and grain weight of 10 maize individual plants at each point were measured during different period of growth and development of crop. The maize biomasses and yield were calculated according to the measured results. Crop quality was determined by routine method.

Investigation of height growth of shelterbelt belts

Investigation of tree height growth was carried out in Suihua and Qiqihaer of Heilongjiang Province, Sipingii and Baicheng of Jilin Province, Fuxin and Chaoyang of Liaoning Province, Chifeng and Tongliao of Inner Mongolia by establishing temporary plots. Poplar as main tree species was investigated. The area of plot was not less than 0.04 hm^2, and the number of individual trees was not less than 50. Average tree as standard tree was chosen for stem analysis to determine the end year of high-speed period and the mature height for protection.

Results and analysis

Wind-checking efficiency of shelterbelt

Shelterbelts can bring impact on some meteorological factors by decreasing wind speed and altering wind directions (Cao 1983). The distance between belts determined in the past was based on the defensive effect of shelterbelt against wind in monodirection of wind. It cannot fully reflect the benefited status of farmland with in shelterbelt net. Our measured result showed that the wind-checking efficiency of the main belts that run from south to north was different under the condition of varied directions of wind (Table 1). The design of shelterbelts must follow a principle that the main belts should be perpendicular to the main direction of harmful wind. The frequency of various wind directions was analyzed and shown as Fig. 2.

Table 1. Wind-checking efficiency of shelterbelt at different times tree height under varied wind directions and wind speed

Wind direction	Ventilation coefficient	Wind speed Range /ms	Height (m)	Wind speed (control) (m/s)	Wind-checking efficiency (%)						
					1H	5H	10H	15H	20H	25H	30H
Southeast	0.59	3.0-6.5	5	6.52	11.5	37.1	21.6	21.9	27.5	20.4	37.4
			1.5	4.92	18.9	35.2	12.4	14.0	21.5	14.8	36.8
South	0.62	4.9-8.6	5	7.98	42.1	41.7	24.2	21.3	16.0	9.1	0
			1.5	3.58	38.0	34.2	20.1	19.8	9.6	6.1	0
Southwest 1	0.72	7.0-13.8	5	11.7	35.0	30.6	20.3	17.3	13.3	6.2	0
			1.5	9.82	16.0	26.9	18.7	15.3	10.2	5.9	0
Southwest 2	0.59	4.9-8.6	5	7.15	53.7	41.7	22.1	18.5	13.3	2.5	0
			1.5	5.94	29.6	40.2	16.7	15.5	9.1	2.7	0
West	0.71	3.0-8.6	5	7.60	40.8	35.5	18.4	11.8	9.2	3.9	2.6
			1.5	6.50	15.4	27.7	18.5	13.8	9.2	3.1	1.5
North		3.9-10.3	5	7.7		11.3	7.0	5.8	4.5	7.5	15.8
			1.5	6.9		19.1	3.6	5.8	10.0	11.0	29.0

The analytical results indicated the main belts should be designed to run from northwest to southeast. However, in practice, the forest belts were in fact not completely perpendicular to the main wind direction because many other factors had to be considered. When the forest belt was at an angle of 45° with wind direction, its effective range of wind check was about 25 times tree height (Fig.3). Shelterbelts can protect farmland during the whole growth season of crops from any direction of wind. Fig. 4 showed the distribution field of wind-checking efficiency in all wind directions within shelterbelt net during growth period. From Fig. 4, we can see that the effective range was similar to ellipse, and its short axis was about 150 m, or 11 times tree height. For this 500 m×500m shelterbelt net, the effective protection range of present height of belt was 350 m, or 25 times tree height.

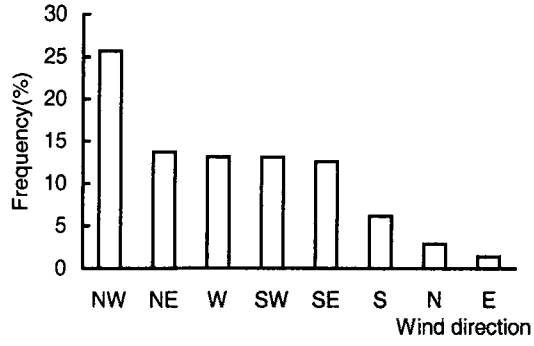
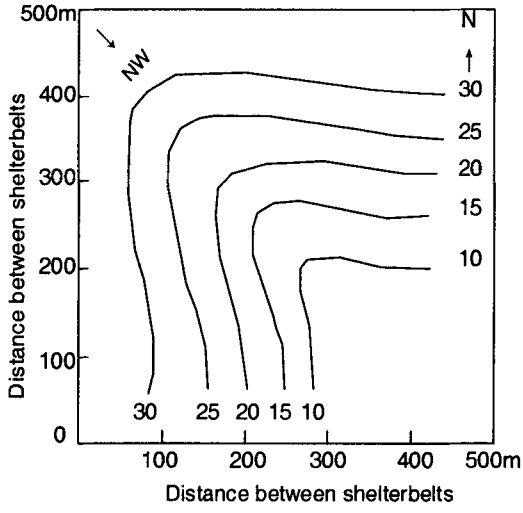


Fig.2 Annual wind direction frequency



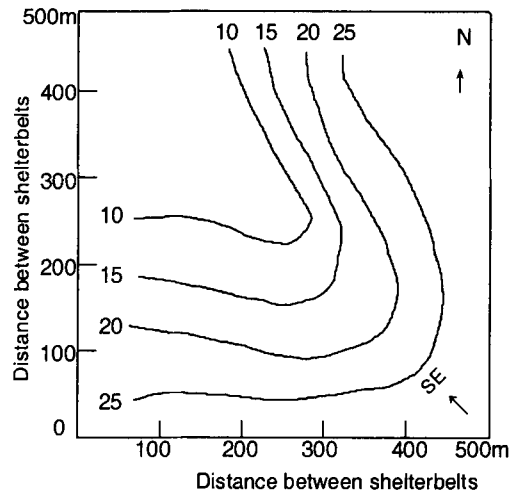


Fig. 3 Distribution field of wind-checking efficiency within shelterbelt net for single wind direction

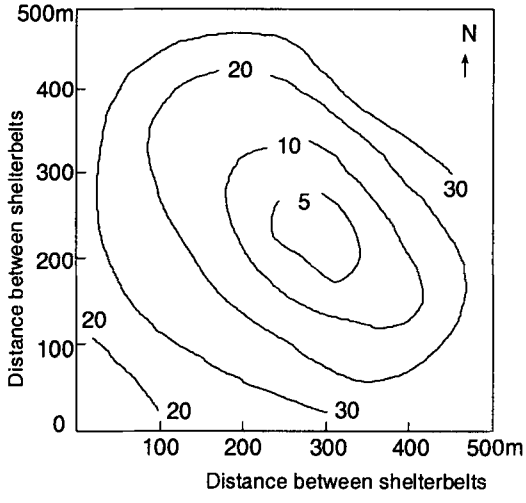


Fig. 4 Distribution field of wind checking effect (%) in all wind directions with in shelterbelt net during growth period

Function of shelterbelt for prevention of frostbite

Shelterbelts take an important role in prevention of early frost. If shelterbelts can alter heavy frost harm into light frost harm, light frost harm into harmlessness, the frostless period will be relatively prolonged. Fig.5 and Fig.6 showed soil temperature distribution within shelterbelt net in early frost day. It can be seen that if the distance between forest belts is reduced by 160 m (11-12 time tree height), the forest belts with an interval distance of 340 m (24-25 times tree height) can alleviate serious harm of early frost.

Integrated effect of climate within shelterbelt net

It is difficult to determine the best interval distance between belts just according to the analysis of single meteorological factor. Integrated effect of climate means a comprehensive field of wind speed, temperature, and water distribution. It was calculated by using the following equation (Hu 1990).

$$WSF=246.52-12.17e+0.58t+6.58u$$

where, WSF is parameter of integrated effect (mm/month), e is average vapor pressure(mm), t is average air temperature (°C), u is average wind speed (m/s) at 1.5 m height within shelterbelt net during the whole growth period in all wind directions.

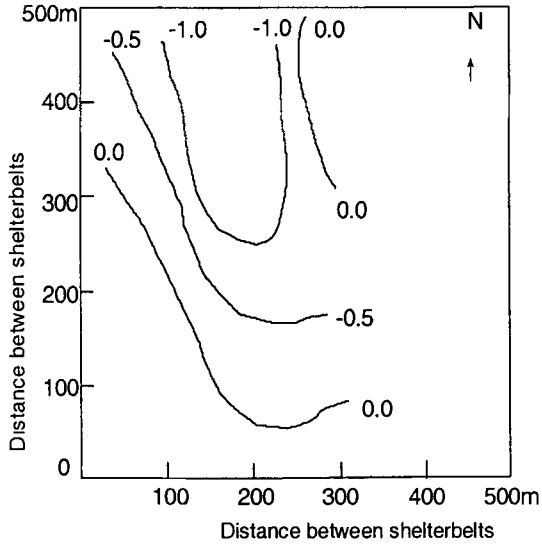


Fig. 5 Distribution field of soil temperature (°C) at early frost time

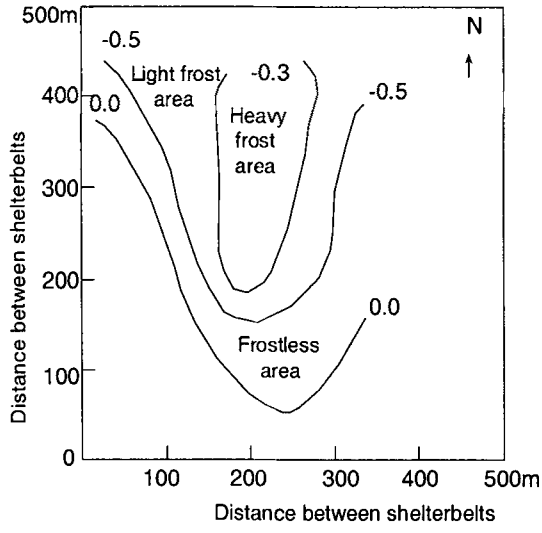


Fig. 6 Distribution field of air temperature (°C) at early frost time

WSF can express the effect of integrated factors including water, temperature and wind. The higher the WSF value is, the lower the protective effect is. A decrease of 10 mm/month *WSF* is equal to an increase of10-mm precipitation per month.

Fig.7 showed the distribution of WSF calculated by using observation results in shelterbelt net from May to July. From Table 2, it can be seen that area with a WSF value below 150 mm/month (contour line) was called benefited area, while the area with WSF value above 150 was called a little beneficial or non-beneficial area. In order to make farmland in beneficial section, present distance between shelterbelts should be adjusted. The distance between main belts or secondary belts should be shortened. The distance between shelterbelts should at least be reduced to 25 times tree height, so that the crops within the whole shelterbelt net can be completely protected.

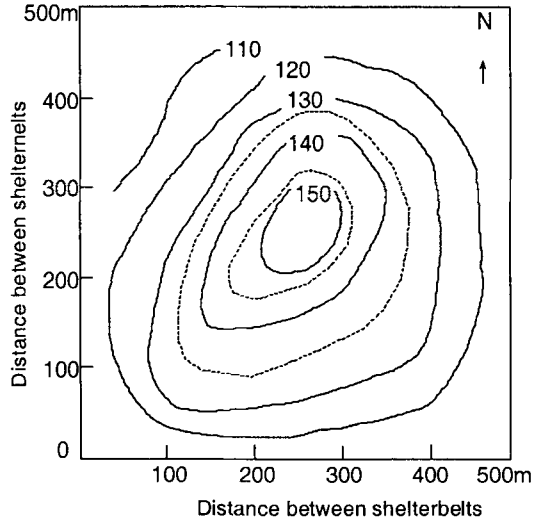


Fig. 7 Distribution field of integrated climate effect (WSF–mm/month) during growth period

Table 2. Integrated climatic effect within shelterbelt net in all wind directions

Parameters	Observation points						Average of whole net	Average difference		Max difference	
	1-1	5-5	18-18	27-27	27-9	9-27		Value	%	Value	%
e (mm)	14.5	11.8	10.6	11.9	12.0	12.4	10.9	1.5	13.8	3.6	33.2
t (℃)	21.6	20.6	20.7	20.5	22.2	21.1	18.6	2.5	13.3	3.6	19.4
u (m/s)	3.6	2.66	3.7 1	2.6	3.4	3.3	3.9	-0.6	-16.6	-1.3	-33.2
WSF(mm/month)	105.8	134.1	54.3	130.8	113.2	129.1	150. 3	-21.2	-14.1	-44.4	-29.6

Effect of shelterbelt net on crop production and quality

Effect of farmland shelterbelt on maize production and quality was very evident. Farmland shelterbelt can obviously increase crop production, except the place at 1 times tree height. Analysis indicated that crop quality within farmland shelterbelt net, including thousand-seed-weight, starch, protein, fat, and organic matter, was greatly improved. In particularly, the increase of protein raised crop quality enormously. The increasing tendency of crop yield declined at 30 times tree height, but the yield and quality of crop were still higher than the control. With regard to crop production and quality, the shelter range of farmland shelterbelts may reach 30 times tree height, or 25 times tree height at least.

Mature height and size of shelterbelt

The mature height of shelterbelts determines the size of shelterbelt net. The protected area by shelterbelt net is direct ratio to height of belt. At present, the farmland

shelterbelt nets in northeastern region of China were almost composed of different varieties of Poplar. The heights at the mature age of protection for those species and varieties of poplar and the calculated size of shelterbelt net was shown in Table 3.

Table 3. The size of farmland shelterbelt nets calculated based on tree height.

Tree species	Height at mature age of protection	Shelterbelt Net size (m×m)
Populus beijingensis	20.1	500×500
Populus canadensis	22.1	550×550
Pioneer poplar	19.6	490×490
Populus simonii	13.6	340×340
Populus pseudo simonii	15.5	420×420
Populus berolinensis Dipp	12.5	310×310
Populus xiaohei	22.1	550×550
Populus shuanyangkuai	20.7	540×540
Populus No.6 beijingensis	16.9	420×420

Results and discussion

According to the analysis of the distribution field of meteorological effect and the yield and quality of crop within the shelterbelt net, the best sheltered range of farmland shelterbelt net was determined as 25 times tree height, and beyond the limits it is regarded as lower benefited area or non-beneficial area.

The absolute distance of sheltered range depends upon the height of shelterbelt, but belt height depends on capable growth height of trees, while tree height varies with tree species. Thus, the absolute sheltered distance is equal to the distance of belt height multiplied by relative sheltered distance.

The poplar species planted, except *Populus simonii*, *Populus pseudo simonii*, *Populus berolinensis Dipp.*, and *Populus No.6 Beijingensis* can reach a sheltered range of 500 m×500m or larger (see Table 3). In fact, the shelterbelts composed of these trees mentioned above were all the early-established shelterbelts, with slow growth speed, bad structure and protective effect, at the beginning of "THREE NORTHS" protective forest project or before. These shelterbelts should be optimized and reconstructed. At present, these trees should be gradually fallen into disuse. Some new varieties of poplars with good characteristics should be introduced and popularized. With the raising management level of farmland shelterbelts, the height of shelterbelt presents an increase trend.

In recent years, some coniferous trees (e. g. Larch, Spruce, Scots pine) with characteristics of longer longevity and higher height at mature age have been introduced into farmland shelterbelts (Zhou 2001). Is the size of shelterbelt net of 500 m×500 m or more suitable? According to the regional characteristics and general management condition, the answer is not. Because of serious scarcity of feedstuff, fuel, muck, and material, farmland shelterbelts serve the needs of protection and timber, in "Three Norths" region, and its economic mature age was taken into more account and most of shelter trees had been cut and utilized for economic purpose before they reached the fully protective age. In addition, the fully sheltering functions of such sized shelterbelt net (500 m×500 m) determined by belt height can only be realized in about 20 years after forestation. Field cannot be fully protected before the age of protective maturation. In particularly, when shelterbelts are being renewed, some blank protective areas in field will occur. It is evident that the 500 m×500 m shelterbelt is too big in terms of specification. According to comprehensive analysis of this paper, 400 m×400 m shelterbelt net in size is recommended for this region. Such sized shelterbelt net can both bring protective effect and economic effect of farmland shelterbelt into full play and give consideration to cropping habits of northeastern China.

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